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NP9 1RH

1. Your reference — CTV/P100159GB

2. 0207375.7 — 28 MAR 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — Hardide Limited, Begbroke Science Park, Sandy Lane, Yarnton, Oxfordshire, OX5 1PF

   Patents ADP number *(if you know it)* — 835290800 1

   If the applicant is a corporate body, give the country/state of its incorporation — England and Wales

4. Title of the invention — Cutting tool with hard coating

5. Name of your agent *(if you have one)* — Harrison Goddard Foote

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* — Belgrave Hall, Belgrave Street, Leeds, LS2 8DD

   Patents ADP number *(if you know it)* — ~~1457 1001~~ 7631310002

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
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Claim *(s)*	3	
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Any other documents *(please specify)*	1	Cover letter, fee sheet

11. I/We request the grant of a patent on the basis of this application.

Signature

Date 28 March 2002

12. Name and daytime telephone number of person to contact in the United Kingdom — Chris Vaughan — 0113 233 0100

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CUTTING TOOL WITH HARD COATING

The present invention relates to knives and other cutting tools having blades provided with a hard laminar or amorphous coating or coatings.

The sharpness of the cutting edge of a knife blade or similar cutting tool is an important characteristic for both domestic knives and industrial knives, as well as for cutting tools in general.

It has long been known that the hardness of a blade material is an important contributor to the ability of a cutting edge of the blade to retain sharpness, as a cutting edge made of softer materials quickly becomes blunt. On the other hand a knife blade is often made as a thin strip or as a sheet, and its edge must have some flexibility so as to avoid brittle fracture or chipping when used. The two characteristics of hardness and flexibility or toughness often contradict with each other as most hard materials are typically brittle and easy to fracture.

Historically various techniques including quenching, heat treatment or alloying have been used to achieve the best combination of these two characteristics.

Attempts have been made to make a knife blade with a hard coating. US 6,109,138 describes a knife blade with one side of its edge coated with a particulate material in a matrix. It is stated that the matrix is softer than the particulate material, and the coating is such that a considerable number of the particulates project from the matrix thereby defining a cutting tip on the blade edge. This knife blade has enhanced edge retention characteristics. However, the edge formed by the separate particles of hard material projecting from matrix does not provide a smooth cutting action. This coating process also does not allow a thin coating to be produced - the coating

thickness is typically above 20-25 microns, and this sets a limitation on the sharpness that can be achieved with a blade having such a thick hard coating layer.

European patent application no. 93303062.9 describes a hard coating having a columnar crystal structure that extends away from a surface of a blank and to an outer face of the coating. However, the mechanism of wear and fracture in the columnar-structured coating does not provide an optimal structure for edge sharpness.

These techniques, although enhancing the edge retention characteristics of a blade, do not enable a smooth and sharp scalpel-like blade to be formed. This is particularly important when the blade is used to cut thin paper (such as tissue) and similar materials that can easily be ripped or torn by an uneven edge.

US 5,799,549 describes razor blades with both sides coated with an amorphous diamond coating having a thickness of at least 400 angstroms, typically about 2000 angstroms. This coating imparts stiffness and rigidity to a thin blade. However, the coating, which has a sub-micron thickness (400 angstroms is equal to 0.04 microns, 2000 angstroms is equal to 0.2 microns) and is formed on both sides of the blade, does not provide for a self-sharpening effect as the blade is used.

Embodiments of the present invention seek to provide further improvements in cutting blade construction so as to facilitate cutting, in particular of soft materials that could easily be damaged by tearing or rupture, while maintaining edge retention characteristics of the blade.

Through extensive experimentation and microscopic observations of the wear mechanisms of various coatings, the present applicant has discovered that the best cutting action can be achieved by using an optimal coating structure and a

combination of coating properties including hardness, thickness and friction coefficient.

Coatings substantially harder than the blade material are found to reduce the wear rate of the cutting blade. When one side of a blade has the hard coating, this side will wear significantly less than the other side having no coating. As the blade is used to cut various materials, micro-wear results in a gradual removal of material from the non-coated side of the blade.

As a result, after some use the edge is comprised mainly of the hard coating layer, supported from one side by the base blade material. At this stage the behaviour of the coating depends on its microstructure. A coating consisting of particulate material in a softer matrix will have the matrix removed by wear, leaving the particulates projecting from the matrix and forming a substantially uneven edge.

A hard coating having a columnar structure will typically fracture along boundaries between the columnar micro-crystals. When the blade base material is removed by wear, leaving the coating edge with insufficient support, small micro-crystalline particles will break away from the coating. In this event, the edge sharpness is defined by the thickness of the coating layer. A coating more than 2 microns thick typically does not provide sufficient sharpness, and to improve its cutting ability this type of blade is often made with serrations/scallops to the non-coated side. This again makes the edge essentially uneven and affects the cutting action.

According to a first aspect of the present invention, there is provided a cutting tool having a cutting edge made of a first material or materials, the cutting edge being coated on one side thereof with a second material substantially harder than the first material or materials, characterised in that the second coating material has a layered or laminar microstructure.

Coatings having a layered or laminar microstructure exhibit different behaviour to the known coatings for cutting edges. When the blade substrate material is worn away and does not provide sufficient support for all of the coating, micro-particles of the coating break away following the layered or laminar structure pattern. This leaves a thinner coating on the blade edge that enhances the edge sharpness. The edge is smooth and scalpel-like and makes a smooth and clear cut, unlike saw-like blades that can tear or rupture the material being cut.

According to a second aspect of the present invention, there is provided a cutting tool having a cutting edge made of a first material or materials, the cutting edge being coated on one side thereof with a second material substantially harder than the first material or materials, characterised in that the second coating material has an amorphous microstructure, and in that the second coating material has a thickness from 0.1 to 25 microns, preferably from 0.1 to 5 microns.

In some embodiment, the amorphous coating thickness may be from 0.5 to 25 microns, preferably 0.5 to 5 microns.

An amorphous coating, for example a diamond-like coating, tends to wear uniformly without leaving rough edges, and due to its hardness tends to maintain its sharpness.

Experiments made by the present applicant with various coating thicknesses have shown that to achieve a self-sharpening action, the coating must be sufficiently thick, and preferably at least 2-3 microns. On the other hand, coatings thicker than 15-25 microns generally do not provide sufficient sharpness. An optimal coating thickness is therefore within this range of thicknesses.

The present applicant has also discovered that coatings having a low coefficient of friction and coatings having a smooth surface facilitate blade movement while cutting and further contribute to a smooth cutting action and cut quality. This appears to be particularly useful for cutting soft and weak materials like thin paper, which is easily damaged by tearing or rupturing.

The present invention can be applied in relation to various types of knives or cutting tools, such as for example an ordinary domestic knife, a disk shaped rotary knife used in industry for cutting paper, a guillotine-type knife, and cutting tools of various shapes. The invention can be applied in relation to tools for cutting metal, wood and/or plastics (among others), including saws, planes, drills and other machining tools.

The blade can be made either as a double-bevelled or as a single-bevelled blade. In the case of a single-bevelled blade, the coating is formed on a flat side of the blade; in the case of a double-bevelled blade, either side of the blade can be coated.

Various coating technologies can be used for deposition of the coating material, among them Chemical Vapour Deposition (CVD) and Physical Vapour Deposition (PVD).

CVD tungsten and tungsten carbide coatings described in PCT/RU99/00037 have been used by the present applicant to produce a hard coating on a knife blade. When applied to steel, such coatings generally comprise an inner sub-layer usually made of nickel, copper or other metals (preferably resistant to fluorine), a layer of metal tungsten and further even harder layers containing tungsten carbide. Coatings of thickness from 1 micron up to 25 microns, and hardness from 10GPa up to 40GPa were applied. The coating preferably has a low coefficient of friction, typically ranging from 0.1 up to 0.2 against steel. Extensive experimentation was used to

identify the coating parameters to provide the advantages of the present invention, including the coating structure, thickness, hardness and friction coefficient.

Another coating process used for this invention is a plasma-assisted CVD diamond-like coating process. This process involves decomposition of hydrocarbons in a plasma discharge in a vacuum chamber evacuated down to a pressure of 10^{-3} to 10^{-4} Torr, and a substrate temperature of at least 20°C. During the coating process, which may last approximately one hour, the coating can be produced with a thickness from 100 Angstrom up to 30 microns, with a hardness ranging from 40GPa up to 70GPa. This coating also has a smooth surface and a very low coefficient of friction, typically between 0.08 and 0.1.

After depositing the coating on one side of a cutting edge, the other side may be additionally sharpened by grinding or by any other technique. This forms an edge consisting of the hard coating layer and the basic blade material, usually steel. In the course of use, the basic blade material is removed by wear and abrasion, leaving a thin layer of the hard coating. When the basic blade material is not sufficient to support the hard coating, microscopic pieces of the coating may be broken away, typically following a layered pattern of the coating structure. This gives a smooth scalpel-like blade edge with sharpness that can not be achieved with thicker coatings or coatings having a columnar structure. Use of the blade actually enhances the edge sharpness.

A smooth scalpel-like blade edge with enhanced sharpness made using the present invention is a particular advantage when the blade is cutting soft materials that could be easily damaged, for example thin toilet tissue. It has also been found by the present applicant that to achieve this scalpel-like blade, a sharpening process should include a stage of dressing or sharpening with a sharpening tool moving along the cutting edge to remove burrs and projecting areas of the coating or substrate material.

EXAMPLES

The examples given below illustrate the invention specifically in relation to the use of CVD and amorphous coatings. However, these examples are not to be taken as limiting the scope of the invention to those specific processes, since other processes may also have the properties required.

Example 1.

A set of nine domestic knives made of stainless steel were coated with CVD coating, consisting of layers of nickel, tungsten and tungsten carbide. The knives were positioned in a vacuum chamber so that one side of each knife was masked. The coating was produced with three different thicknesses: three blades with a coating 6 microns thick, three blades with a coating 9 microns thick, and three blades with a coating 13 microns thick. The other side of the blade was sharpened by grinding, including edge dressing by way of a sharpening tool being moved along the cutting edge so as to remove burrs and projecting parts of coating and steel. The coating produced had a friction coefficient against steel of 0.14.

The knives were tested on a test rig to cut 50mm thick cardboard blocks under a fixed load by reciprocating movements, while the number of strokes required to cut the block was counted.

All the tested knives cut the first block of cardboard in approximately 5 strokes, and this number of strokes was generally maintained and gradually reduced during the tests which involved cutting 100 blocks. For comparison, a standard non-coated sharp knife cut the first block in 2-3 strokes, but the number of strokes increased up

to 70-100 when it cut the 5th block as a result of the edge becoming blunt very quickly.

This test demonstrated that the coating provides a self-sharpening cutting edge.

Example 2.

Two disk rotary knives were coated with a CVD coating consisting of layers of nickel, tungsten and tungsten carbide. The disks were positioned in a vacuum chamber so that one side of the knife had a coating of 5 microns in one case and 10 microns in the other. The disk knives were sharpened by dressing the edge and grinding another side of the edge, and observation of the edge under a microscope showed it to be smooth with a sharp scalpel-like edge.

Tests of the knives showed enhanced cutting action without damage to the material being cut.

Example 3.

Disk rotary knives used for cutting skin grafts in plastic surgery were coated with a diamond-like coating 0.5 microns thick. The coating had a friction coefficient against steel of 0.1.

Tests showed that the coated edge maintained its sharpness up to five times longer than a non-coated edge, without any need to re-sharpen the knife

Example 4.

Cutting tools for cutting polyethylene film from a polyethylene block by a process known as skiving were made of tool steel as a long bar with one or two corners profiled to make a sharp cutting edge. Because of the abrasive nature of the material and the process the tool lasted approximately one day. Two cutting tools were coated

with CVD tungsten carbide on a flat side of the bar. The coating had a friction coefficient against steel of 0.14.

The tool was used for cutting polyethylene film, and the tests showed that the tool sharpness was maintained over a period at least four times longer than the normal tool life.

Example 5.

A blade of a plane was coated with CVD tungsten carbide so that a flat side of the blade had a hard coating. The other, bevelled, side of the blade was sharpened.

The plane maintained its blade sharpness for an operational period up to 3 times longer than a period after which a standard blade requires sharpening, before testing was stopped. It is expected that the coated blade will maintain its sharpness for even longer periods of operation.

Example 6.

A metal cutting tool made of tool steel was coated with multi-layer CVD tungsten carbide on one side of its cutting edge. The coating consisted of a 1 micron nickel sub-layer, a 0.5 micron tungsten layer followed by alternating layers of tungsten carbide approximately 1.5 micron thick and tungsten approximately 0.5 micron thick, up to a total thickness of 10 microns. The coating had a friction coefficient against steel of 0.14.

The tool was used for cutting aluminium, and tests showed that the tool had enhanced cutting quality, reduced sticking of aluminium shavings, and the tool remained sharp for at least four times longer than a normal non-coated tool. The tests were then stopped, but it is expected that the coated tool could continue cutting aluminium while remaining sharp due to the coating, thereby ensuring an enhanced quality of cut.

CLAIMS:

1. A cutting tool having a cutting edge made of a first material or materials, the cutting edge being coated on one side thereof with a second material substantially harder than the first material or materials, characterised in that the second coating material has a layered or laminar microstructure.

2. A tool as claimed in claim 1, wherein the coating material has a friction coefficient against steel of 0.2 or less.

3. A tool as claimed in claim 1 or 2, wherein the coating is produced by Chemical Vapour Deposition in a vacuum chamber at a pressure lower than atmospheric pressure and at a temperature above 400°C, preferably from 480°C to 650°C.

4. A tool as claimed in any preceding claim, wherein the coating has a thickness from 1 to 25 microns, preferably 3 to 10 microns.

5. A tool as claimed in any preceding claim, wherein the coating has a surface with roughness Ra of 0.8 microns or less, preferably 0.5 microns or less.

6. A tool as claimed in any preceding claim, wherein the coating comprises layers of tungsten, tungsten carbides and/or mixtures of tungsten with tungsten carbides alloyed with fluorine in amounts ranging from 0.0005 to 0.5 wt%.

7. A tool as claimed in any preceding claim, wherein the coating has an innermost layer of tungsten, on which are provided alternating layers of differing hardness, consisting substantially of tungsten carbides, tungsten, and mixtures of tungsten carbides with tungsten.

8. A cutting tool having a cutting edge made of a first material or materials, the cutting edge being coated on one side thereof with a second material substantially harder than the first material or materials, characterised in that the second coating material has an amorphous microstructure, and in that the second coating material has a thickness from 0.1 to 25 microns.

9. A tool as claimed in claim 8, wherein the coating material has a thickness from 0.1 to 5 microns.

10. A tool as claimed in claim 8 or 9, wherein the coating has a friction coefficient against steel of 0.1 or less.

11. A tool as claimed in claim 8, 9 or 10, wherein the coating is a diamond-like coating produced in a vacuum chamber at a pressure lower than atmospheric pressure and at a temperature from 20 to 60°C.

12. A tool as claimed in any one of claims 8 to 11, wherein the coating has a thickness of 0.1 to 5 microns, and a surface roughness similar to a surface roughness of the first material or materials.

13. A tool as claimed in any preceding claim, wherein the tool is a knife.

14. A tool as claimed in claim 13, wherein the knife is a disk rotary knife.

15. A tool as claimed in any one of claims 1 to 12, wherein the tool is a metal cutting tool.

16. A tool as claimed in any one of claims 1 to 12, wherein the tool is a wood cutting tool.

17. A tool as claimed in any one of claims 1 to 12, wherein the tool is a plastics cutting tool.

18. A cutting tool substantially as hereinbefore described.

ABSTRACT

CUTTING TOOL WITH HARD COATING

There is disclosed a cutting tool having a blade coated on one side with a hard coating having a laminar, layered or amorphous microstructure. The coating tends to wear evenly and smoothly, thereby keeping a cutting edge of the cutting tool smooth. Furthermore, by coating the cutting edge on one side only, the cutting edge becomes self-sharpening.

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